E-24-61N

Final Report for Period: 08/2004 - 07/2006
Submitted on: 10/31/2006
Principal Investigator: Bodner, Douglas A.
Award ID: 0423360
Organization: GA Tech Res Corp - GIT
Title:
Hybrid Models for Simulation-Based Prototyping of Decision Logic in Material Flow Systems

Project Participants

Senior Personnel

Name: Bodner, Douglas
Worked for more than 160 Hours: Yes
Contribution to Project:
He supervised all aspects of project, published project results to date, and handled administrative matters.

Post-doc

Graduate Student

Name: Wang, Ke
Worked for more than 160 Hours: Yes
Contribution to Project:
She performed modeling and implementation tasks associated with the project. She was funded with the project grant.

Name: Xu, Sheng
Worked for more than 160 Hours: Yes
Contribution to Project:
He performed modeling and implementation tasks associated with the project. He was funded with the project grant.

Undergraduate Student

Name: Chauhan, Shakti
Worked for more than 160 Hours: No
Contribution to Project:
Developed Matlab implementation of compound European options formulae, as well as methods to generate code for option evaluation at any stage n of a multi-stage decision process. Integrated Matlab code with Java-based discrete-event simulation library so that the options evaluation can be performed within a simulation model. Received course credit for undergraduate research.

Name: Hasegawa, George
Worked for more than 160 Hours: No
Contribution to Project:
Developed ARENA models of R&D organizations and ran experimental analysis for alternate management decision strategies. Received course credit for undergraduate research.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

This project has engaged in the following activities:

1. Specification of a reference model for material flow systems identifying important elements and their interactions with one another. A reference model is a canonical description of a particular class of systems for modeling and analysis purposes.

2. Classification of material flow systems to support reusability in decision logic design. This classification was extended since the last interim report and was done along the lines of material flow patterns, flow technologies, event types, decision problems, possible algorithms, information required, and control points.

3. Specification and implementation of a generic first-generation decision logic unit. A decision logic unit is the fundamental unit within the simulation model that makes decisions, analogous to a decision-maker in the system being modeled. Identification of initial set of modules required by this unit, including routing, dispatching and induction. Modules contain fundamental decision logic within decision logic units. Implementation of these modules. Since the last interim report, decision logic units have been enhanced to include scheduling capabilities.

4. Integration of process-interaction simulation methods with the decision logic units. The process-interaction simulation methods are used to model the physical flow system, while the decision logic units model the decision logic that governs flow. The process-interaction methods are from the DSOL simulation package (open-source simulation product), while the decision logic units are implemented using the Java(tm) language.

5. Development of case study models to demonstrate concepts. Case study systems include a small-scale semiconductor wafer fab, a hospital surgery ward and intensive care unit, and a multi-stage R&D project selection system. Since the last interim report, case studies have also included an automated guided vehicle system, a large-scale 300mm semiconductor fab, a 200mm semiconductor fab, a hospital staff scheduling system and an enhanced version of the multi-stage project selection system. A related project used this modeling approach to study multi-stage R&D in the paper and pulp industry. Simulation code was integrated with outside computational engines for advanced decision logic, including:
- patient selection for surgery slots via a modified knapsack integer programming formulation (CPLEX/Concert package),
- staff scheduling to meet patient service requirements (CPLEX/Concert package),
- project selection in a multi-stage project investment environment using valuation by compound real options (MATLAB package), and
- automated generation of code for MATLAB compound option computations at any stage n of a compound option (Java).

6. Using activity cycle diagrams to model the process-interaction representation of the physical system, initial metrics have been developed to represent the complexity of a simulation model's physical elements. Current work is seeking to integrate these metrics with metrics used to study complexity of decision logic (e.g., algorithms) for a method to measure the overall complexity of simulation models.

Findings:

The findings from this project are:

1. The reference model for material flow systems supports a richer representation for physical material flow systems than currently allowed by commercial process-interaction simulation packages. This is achieved by the inclusion of such system elements as operators and 'active material' (i.e., customers who flow through a system, but have decision-making capability). These present opportunities for additional modeling research.

2. The process-interaction method can be successfully integrated with a decision logic based formalism. This integrated approach has proven useful for representing complex decision logic within a simulation model, as demonstrated via case studies.

3. Classifying material flow systems has proven useful for identifying and parameterizing decision modules needed for decision logic units.

4. Code generation can be used to model decision logic.

5. Initial complexity measures for simulation models have been developed.

Training and Development:
The research skills and experience gained by project participants include the following:

1. Ability to use advanced simulation modeling techniques to model complex systems.

2. Ability to formulate decision problems within the context of a material flow system operation, and to integrate solution methods with the simulation model.

3. Ability to decompose problems to facilitate modeling and to enhance computational efficiency in distributed simulation systems.

4. Ability to test concepts via case study analysis and implementation, and to design experiments to test effectiveness of different decision approaches in a material flow system.

5. Ability to create code generation methods for decision logic within simulation models.

6. Ability to analyze model complexity.

Outreach Activities:
General information concerning the project has been posted to my website.

Journal Publications

Bodner, D. A., K. Wang and S. Xu, "Advanced Decision Logic in Simulation of Material Flow Processing Networks", Proceedings of the 2005 Winter Simulation Conference, p. 1359, vol. , (2005). Published

Bodner, D. A., "Hybrid Models for Simulation-Based Prototyping of Decision Logic in Material Flow Systems", Proceedings of the 2005 NSF DMII Grantees Conference, p. N/A, vol. , (2005). Published

D. A. Bodner, K. Wang and S. Xu, "Modeling Decision Logic in Material Flow Processing Networks", Proceedings of the 2006 NSF Design, Service and Manufacturing Grantees and Research Conference, p. N/A, vol. , (2006). Published

D. A. Bodner and W. B. Rouse, "Understanding R&D Value Creation with Organizational Simulation", Systems Engineering, p. , vol. , ( ). Accepted

Books or Other One-time Publications

Web/Internet Site

URL(s):
http://www.isye.gatech.edu/people/faculty/Doug_Bodner/research/projects/nsf-sim/index.htm
Description:
This site provides general information about project goals and activities.

Other Specific Products

Product Type:
Presentation

Product Description:

Presentation titled "Modeling Decision Logic in Material Flow Systems," presented at the 2005 Industrial Engineering Research Conference, May 15-17, Atlanta, Georgia.

Sharing Information:

In addition to the presentation at the IE Research Conference, it will be posted to my website.

Product Type:

Software (or netware)

Product Description:

Decision logic unit, a fundamental decision-making entity within a material flow system, implemented as a set of Java classes.

Sharing Information:

This will be used initially in collaborative research, in particular targeting the emerging field of organizational simulation. This is a multi-disciplinary field where our collaborators are from computer science (AI and natural language processing), literature (interactive drama) and architecture (3D world renderings and walk-throughs).

Product Type:

Software (or netware)

Product Description:

Simulation model of 300mm semiconductor wafer fab.

Sharing Information:

This model will be used in collaborative research, as well as in a graduate-level course developed as a result of this project.

Product Type:

Software (or netware)

Product Description:

Simulation model of a multi-stage R&D organization.

Sharing Information:

This model is being used in collaborative research, and will be used in a graduate-level course developed from this project.

Product Type:

Software (or netware)

Product Description:

Simulation model of a hospital surgery ward and intensive care unit.

Sharing Information:

This simulation model will be used in collaborative research, as well as in a graduate-level course developed as a result of this project.

Product Type:

Software (or netware)

Product Description:

Simulation model of a hospital staff scheduling system.

Sharing Information:

This simulation model will be used in collaborative research, as well as in a graduate-level course developed as a result of this project.

Product Type:

Software (or netware)

Product Description:

Simulation model of an automated guided vehicle system.

Sharing Information:

This simulation model will be used in collaborative research, as well as in a graduate-level course developed as a result of this project.

Product Type:

Software (or netware)

Product Description:

Simulation model of a small-scale semiconductor wafer fab.

Sharing Information:

This simulation model will be used in a graduate-level course developed as a result of this project.

Product Type:

Software (or netware)

Product Description:

Simulation model of a 200mm semiconductor wafer fab.

Sharing Information:

This simulation model will be used in collaborative research, as well as in a graduate-level course developed as a result of this project.

Product Type:

Software (or netware)

Product Description:

Code generation software for creating Matlab files to compute compound options valuations, implemented in Java.

Sharing Information:

This software will be used in collaborative research, as well as in a graduate-level course developed as a result of this project.

Contributions

Contributions within Discipline:

The principle discipline addressed by this project is industrial engineering. In this discipline, discrete-event simulation has been used extensively to analyze and help design material flow systems such as factories and warehouses. Increasingly, it is used to analyze supply chains and service systems. These systems embody complex decision logic and information usage to enhance performance.

Traditional simulation methods rely mainly on the process-interaction paradigm, which focuses on the movement of simulation entities through a network of resources and processes. This paradigm is well-suited to modeling the physical flow of discrete units of material through a material flow system. However, it is limited in representing complex decision-making, such as optimization, scheduling/re-scheduling, or advanced evaluative computations (e.g., solving for a set of equations).

This project's contributions are the following:

1. A classification of material flow systems. This classification contributes by allowing subsequent identification of generic decision modules to be included with decision logic units.

2. A reference model for material flow systems. This contributes by identifying elements that must be incorporated into the simulation modeling constructs, especially for purposes of representing decision-making, and for purposes of reusability.

3. A generic decision logic unit that can be used within simulation models.

4. Modeling of complex decision logic within simulation models demonstrated via integration of the decision logic unit within process-interaction simulation, including integration with outside computational solvers.

5. Methods to generate code for decision logic in material flow systems.

6. Initial categorization of simulation model complexity for representation of physical material flow system.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

The results from this project have been used to develop a graduate level course in modeling advanced decision logic in material flow systems.

Topics include:
- Simulation modeling paradigms
- Representing and solving decision problems in simulation
- Interoperability
- Multi-tool integration frameworks
- Applications

This will be offered as a special topics graduate-level course within the School of Industrial & Systems Engineering.

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Organizational Partners

Any Book

Contributions: To Any Other Disciplines

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering